4.5.3.1 Physical Condition

The Lower Reach of Castle Creek is a partly confined system surrounded by an urban setting. The right bank of Castle Creek generally abuts or is close to valley margin with floodplain located along most the left bank (orientated in a downstream direction). Floodplain depressions, which concentrate and convey flow during overbank flow events are present on the western floodplain surface.

A number of pools exist within the creek bed. The pools provide geomorphic diversity and habit niches. There is generally a lack of large woody debris that would provide additional habitat value and geomorphic diversity.

The Lower Reach of Castle Creek appears to be more robust than the Mid Reach. This may be due to an increase in riparian vegetation, albeit mainly exotic species. Vegetation is present along the bank for most the reach. Willows are also growing in-stream and may cause blockages and restrict flows.

A head-cut was identified in Castle Creek immediately upstream of the confluence with Huon Creek. The head cut has been armoured with concrete and rock (Figure 4-39).

Figure 4-39 Head cut that has been armoured with concrete.

4.5.3.2 Vegetation Condition

This reach would have originally been occupied by EVC56 Floodplain Riparian Woodland but now shows only scarce to patchy native tree cover. Parkland adjoins the majority of both banks with a small section of the left bank at the upstream end used for grazing. This reach is heavily infested with woody weeds, particularly upstream of Yarralumla Drive. The left photo in Figure 4-40 is typical of the level of infestation throughout the reach upstream of Yarralumla Drive. The right photo shows parkland adjacent to the creek downstream of Yarralumla Drive and a thin line of exotic trees discontinuously lining the right bank.

Figure 4-40 Creek line upstream in summer (left) and downstream in winter (right) of Yarralumla Drive.

4.5.3.3 Trajectory and Management Implications

- **Further development is planned within the Castle Creek catchment. Water Sensitive Urban design techniques and appropriate riparian vegetation management is required to minimise changes to downstream hydrology, hydraulics, channel stability and sediment transport rates.**
- **The extent and nature of erosion within this reach requires further investigation. The informal bed grade control structure near the confluence with Huon Creek will likely fail in the short to medium term. Once failure has occurred, the head-cut will become active and re-initiate bed deepening within this reach. This has the potential to liberate large volumes of sediment and undermine infrastructure upstream of the head-cut.**
- **The existing willows are contributing to the bed form and channel stability within this reach. Any willow management works undertaken within this reach will need to consider the role the willows provide in relation to channel stability. Conversely, as the willows age, they will have an increasing tendency to collapse into the channel, potentially contributing to bank instabilities.**
- **The section of this reach upstream of Yarralumla Drive is solidly infested with woody weeds. Condition is very poor and can only improve with weed control and replacement with native revegetation.**
- **The downstream reach is also in a relatively stable condition give the current level of management. This reach could be effectively improved through weed control and native plant revegetation.**

4.6 House Creek

House Creek forms at the confluence on Castle Creek and Huon Creek, immediately downstream of Huon Creek Road (Figure 4-41). House Creek flows through an urban setting before joining Wodonga Creek adjacent to the Hume Freeway. Much of the floodplain of House Creek is parkland with a walking/bike path running along the western side of the creek.

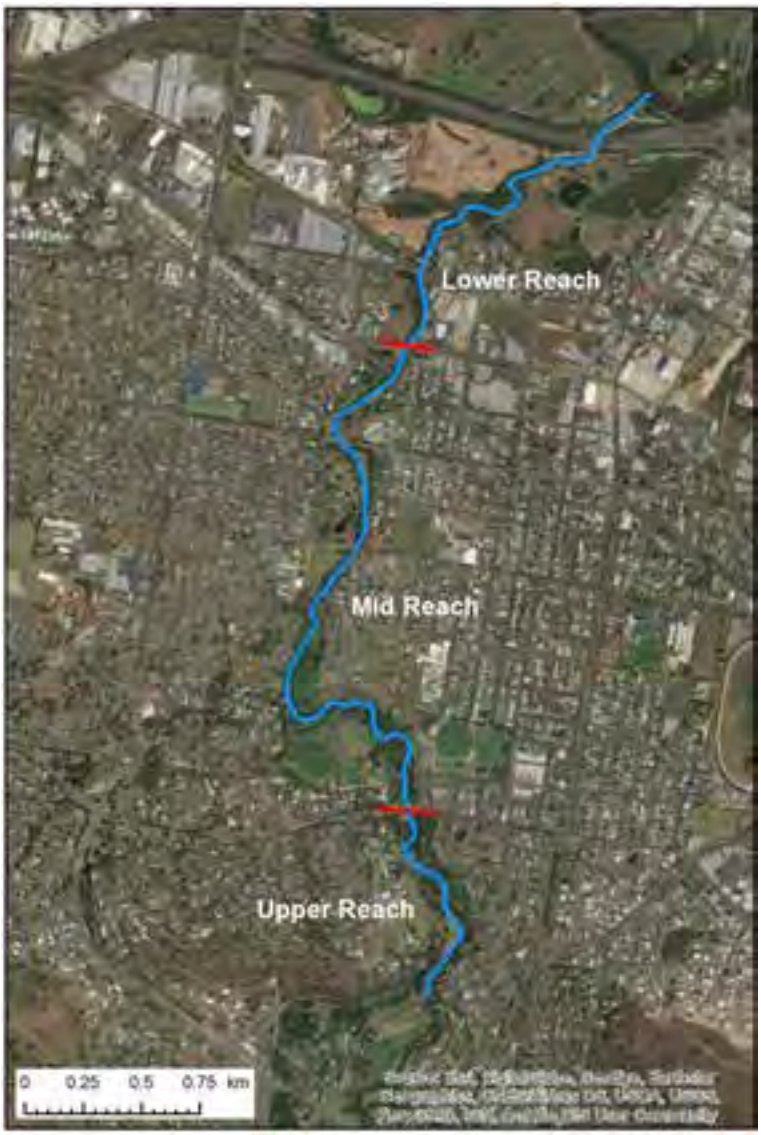

Figure 4-41 House Creek reaches.

4.6.1 Upper Reach

The Upper Reach of House Creek is bound by the confluence of Huon Creek and Castle Creek at the upstream and Pearce Street at the downstream extent (Figure 4-41).

4.6.1.1 Physical Form

The Upper Reach of House Creek is located within a residential urban setting. This reach is partly confined with the creek regularly abutting hillslope on the right bank. The left bank adjoins floodplain which is managed as informal and formal parklands. The adjoining land along the right bank is generally freehold land.

Sediment derived from the Huon Creek catchment is being transported into House Creek. Whilst there is a large sediment deposit at the confluence of Huon Creek and Castle Creek, in-stream sediment deposits were not commonly observed within this reach. This indicates that a considerable proportion of the sediment is being transported through this reach, into downstream reaches.

Bank instabilities are common within this reach. Erosion was often associated where the surrounding floodplain surface is mown to the top of bank and there is an absence of woody riparian vegetation (freehold land, Figure 4-42). Rock beaching was observed in a discrete location.

Figure 4-42 Erosion is evident in an area where the grass is mown to the top of the bank.

4.6.1.2 Vegetation Condition

This reach has been mapped as being EVC56 Floodplain Riparian Woodland. The larger floodplain and presence of very large remnant River Red Gums indicate that this EVC is appropriate for the House Creek riparian corridor.

The vegetation condition varies greatly between the left (western) and right (eastern) sides of the creek. The left bank has a broader floodplain and is known as the Clyde Cameron Reserve (Figure 4-43). This reserve has had extensive management and comprises open mown parkland with stands and individual mature Red Gums scattered across the floodplain and creek bank. The creek bank and near riparian zone is mostly revegetated and mulched, with a diverse mix of trees, shrubs and grasses. These planted riparian areas extend between 2 – 10m off stream and are relatively weed free. A bowerbird and bower were observed within the planted riparian reserve on the left bank during inspections in November 2017. The left bank, although not free of woody weeds, is well maintained and of high quality, with a range of native species and lifeforms.

The right bank, in contrast, is in very poor condition with tree and shrub weeds dominating the majority of the bank's length. There is limited floodplain along most of the right bank and freehold properties extend close to the creek bank. The creek pushes up to the floodplain margin along sections of the right bank and these steep high banks are by nature more difficult to maintain and are often infested by woody weeds. There are some small floodplain pockets off the right bank that are kept clear with mowing, however, the woody weed species are still abundant on the bank and exotics are also being planted.

Figure 4-43 Left bank managed parkland, weed infested right bank.

4.6.1.3 Trajectory

- **House Creek has likely deepened and widened in response to urbanisation within the contributing catchment area.**
- **Bank erosion can be expected to continue to occur on sections of the bank where there is a lack of vegetation. Outside bends will typically be exposed to greater erosion forces and as such can be expected to erode at a greater rate.**
- **Sand will continue to be supplied into the Upper reach of House Creek from Huon Creek for the foreseeable future. The absence of large sand slugs indicate that a considerable proportion of the sediment is being transported into downstream reaches.**
- **The left bank (orientated in a downstream direction) of this reach is currently being well managed, facilitating an improving condition trajectory on that side of the creek.**
- **The right bank is in very poor condition and will remain so unless weed control and native revegetation works are undertaken.**
- **The management regime on the right bank is compromising the weed management works on the left bank as weeds are providing a constant source of propagules, either by wind (e.g. Box Elder, Ash, Black Willow), during flooding (e.g. Crack Willow, Tradescantia) or via other vectors (e.g. birds). A co-ordinated weed management program is required to ensure future works are not compromised.**

4.6.2 Mid Reach

The Mid Reach of House Creek is bound by Pearce Street at the upstream extent and Melbourne Road at the downstream extent (Figure 4-41).

4.6.2.1 Physical Condition

Like the Upper Reach, the Mid Reach of the House Creek is located within a residential and partly confined valley setting. The channel meanders across the floodplain, abutting the valley margin on both sides. The land use along both banks of House Creek is both informal and formal parkland. Bike tracks, open spaces and trees are situated within the floodplain/parkland areas.

Discontinuous bank erosion was commonly observed across the Mid Reach of House Creek. The bank erosion was primarily identified where there was a lack of vegetation. Rock beaching was observed at one location.

Between Brockley Street and Lawrence Street, large sand deposits were evident (Figure 4-44). The sand has deposited across the entire channel bed, forming a uniform bed profile with a low flow channel meandering through the sand.

A number of head-cuts were identified a short distance upstream of Melbourne Road indicating that the reach is undergoing deepening (Figure 4-45). The head-cuts were all stabilised by willow roots or informal rock chutes.

Figure 4-44 Looking downstream at a large sand deposit in House Creek.

Figure 4-45 Head-cut in House Creek, approximately 50 metres upstream of Melbourne Road, that is currently stabilised by willow roots.

4.6.2.2 Vegetation Assessment

The vegetation throughout this reach is variable. Generally, the floodplains are a combination of informal and formal parklands with established native trees (mostly Red Gum) and planted exotic trees, including rows of Oak and Poplar (Figure 4-46, left). The creek line has good cover of native trees and shrubs; however, the creek also has major woody weed infestations, particularly through the middle part of the reach from Willow Park to below the footbridge within Les Stone Park.

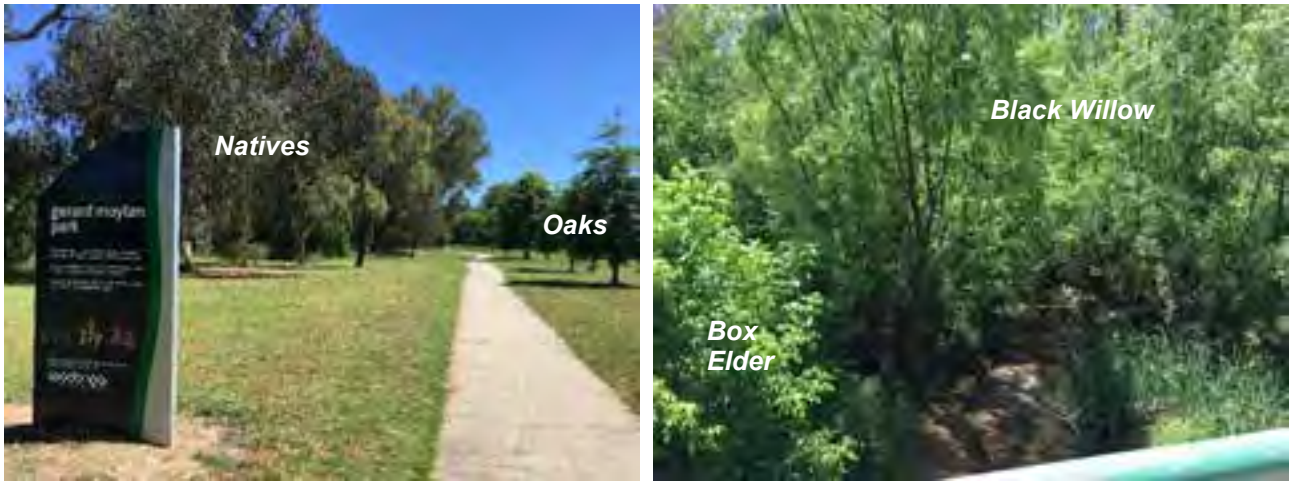

Figure 4-46 Semi-formal parkland floodplains, Black Willow infested channel downstream from Brockley Street.

Willow (Weeping and Black) and Box Elder (Figure 4-46, right) are the more prevalent weeds within this middle section of the reach. Both the Black Willow and Box Elder are spreading from wind borne seed and colonising the banks and unmown verges. Black Willow in particular will colonise moist sand bars within the channel

(Figure 4-46, right) and have the potential to cause substantial blockages, reduce channel capacity and deflect flow.

Two infestations of the invasive perennial aquatic weed, Parrot's Feather (*Myriophyllum aquaticum*) were observed in slight backwaters, just upstream of Lawrence Street, within Les Stone Park (Figure 4-47).

Figure 4-47 Parrots Feather infestations upstream of Lawrence Street, closeup of stem and leaves.

4.6.2.3 Trajectory and management implications

- **House Creek has likely deepened and widened in response to urbanisation within the contributing catchment area.**
- **The supply of sediment into this reach is depositing in-stream and impacting upon channel capacity and in-stream diversity. The management of sediment will require intervention within the upstream reaches, where the sediment is sourced from.**
- **The existing willows are contributing to the bed form and channel stability within this reach. Any willow management works undertaken within this reach will need to consider the role the willows provide in relation to channel stability. Conversely, as the willows age, they will have an increasing tendency to collapse into the channel, potentially contributing to bank instabilities.**
- **The rehabilitation goals within this reach will be strongly related to the riparian management practices (zones) that exist within this reach.**
- **The channel and near riparian zone adjacent to Willow Park generally has lower weed densities and with on-going maintenance could maintain good native vegetation and stream condition.**
- **The majority of the remaining reach from Willow Park to Melbourne Road has relatively high woody weed infestation. This section is in poor condition and the ongoing seeding of weed species will further choke and degrade the creek line. This reach requires substantial control works and ongoing management to reduce weed cover and competition and allow native vegetation to thrive and recruit naturally.**

4.6.3 Lower Reach

The Lower Reach of House Creek extends from Melbourne Road to the confluence with Wodonga Creek (Figure 4-41).

4.6.3.1 Physical Condition

The Lower Reach of House Creek transitions from a partly confined system to an unconfined system as it enters the Wodonga Creek floodplain downstream of the Hume Freeway. Wodonga Creek will become a major hydraulic control in this reach of House Creek. The land use surrounding the creek transitions from an urban setting with residential, parklands and industry to informal Crown land and occasional grazing downstream of the Hume Freeway.

The Lower Reach appeared to be more robust than the Mid Reach of House Creek. This may be influenced by the dense riparian vegetation presence and reduction in hydraulic slope. Sand has deposited in the bed of House Creek. As a result, there is lack of geomorphic diversity through much of the reach.

Approximately 200 metres upstream of the Hume Freeway, the channel becomes deeper and wider and has been lined with a substantial amount of quarry rock on both the bed and banks through to the confluence with Wodonga Creek (Figure 4-48). It is not clear why the rock has been placed over this large extent, however it is assumed that the rock has been used to mitigate channel deepening and bank erosion and to protect the Hume Freeway bridge crossing.

Figure 4-48 Rock lined channel of House Creek located under the Hume Freeway.

4.6.3.2 Vegetation Assessment

This reach is extremely weedy from Melbourne Road, through Phil Locke Adams Park and Felix Grundy Park to the middle of Belvoir Park. Phil Locke Adams Park is less formal than the Parks upstream and the creek channel is severely infested with woody weeds, particularly Black Willow, Ash, Box Elder and Poplar. There is a large infestation of Blue Periwinkle on the ground layer within Phil Locke Adams Park and English Ivy is threatening to smother mature Red Gums (Figure 4-49).

Figure 4-49 House Creek weeds surrounding Red Gums within Phil Locke Adams Park.

Felix Grundy Park is situated along the right bank of House Creek from Forrest Mars Avenue to Dick Street and Belvoir Park. The Park is mown and contains scattered natives and exotic ornamental trees, while the adjacent creek line is infested with woody weeds including Box Elder, Willow and Robinia (Figure 4-50). The left bank hillslope adjacent to the abattoir has a large infestation of Tree of Heaven and the lower floodplain is also infested with a variety of woody weeds.

From the middle of Belvoir Park, under the freeway to Wodonga Creek, the channel is rock lined, and the woody weeds are mostly controlled.

Figure 4-50 Heavily infested channel downstream of Forrest Mars Avenue, Felix Grundy Park with Tree of Heaven infesting hillslope adjacent to abattoir.

4.6.3.3 Trajectory and management implications

- **House Creek has likely deepened and widened in response to urbanisation within the contributing catchment area.**
- **Deposition will continue to occur in this reach due a reduction in valley slope and therefore a reduction in flow energy.**

- **The supply of sediment into this reach is depositing in-stream and impacting upon channel capacity and in-stream diversity. The management of sediment will require intervention within the upstream reaches, where the sediment is sourced from.**
- **Riparian vegetation is contributing to bank stability within this reach.**
- **The creek line and lower floodplain is heavily infested with woody weeds that will continue to impact on the native species present. If left uncontrolled, these weeds will slowly outcompete existing native plants and prevent natural recruitment.**
- **The weeds on the hillslope adjacent to the abattoir may be subject to high nutrient runoff. Therefore, weeds on that hill slope should only be controlled and replaced with natives if they are not currently performing nutrient stripping.**

4.7 Jack-in-the-Box Creek

Jack-in-the-Box Creek drains the northern face of Bears Hill before flowing north through an urban environment to its confluence with Wodonga Creek. For the purposes of this Water Action Plan Jack-in-the-Box Creek has been split into three reaches (Figure 4-51). These being:

- White Box Rise Reach.
- The Piped Reach.
- The Lower Reach.

A condition summary map is provided in Appendix A.

Figure 4-51 Jack in the Box Creek reaches.

4.7.1 White Box Rise Reach

The White Box Rise Reach of the Jack-in-the-Box Creek is the upstream most reach, extending to Thomas Mitchell Drive (Figure 4-51).

4.7.1.1 Physical Condition

The catchment of the White Box Rise Reach of Jack-in-the-Box Creek includes the steep slopes of Bears Hill, the Bandiana Army Barracks and White Box Rise. A number of small tributaries converge around the corner of Victoria Cross Parade and Chapple Street to form Jack-in-the-Box Creek. The primary channel is an open swale that flows through the eastern side of the Army Barracks (Figure 4-52).

White Box Rise has undergone significant development over the last ten years and development is still occurring. During the site inspection, it was noted that the sediment management on the White Box Rise development area was poor to non-existent, with rill erosion present across the area under development

(Figure 4-53). In one location, a sand bag was position on the downstream side of a side entry pit to direct the untreated run-off from the earthworks site into the side entry pit (Figure 4-54).

It is assumed that the stormwater from the White Box Rise development is directed to the four treatment ponds at the Wodonga Racecourse and Recreation Reserve. A significant volume of deposition is evident within the upstream pond immediately downstream of the inlet (Figure 4-55).

A small channelised tributary flows through woodlands along the western edge of White Box Rise. Erosion is present immediately upstream of the Victoria Cross Parade culvert crossing within this tributary (Figure 4-56). The erosion incorporates bed deepening, associated bank erosion and tunnel erosion within dispersive soils and may have been triggered by the construction of the culvert crossing. Rock armouring has been placed within the channel, however the erosion is occurring adjacent to the placed rock.

Figure 4-52 Grassed swale that is one of the main tributaries of Jack-in-the-Box Creek.

Figure 4-53 Rill erosion has occurred at the White Box Rise development.

Figure 4-54 Sand bags being used to direct sediment into a side entry pit at the existing development of White Box Rise.

Figure 4-55 Significant volume of sediment in the upstream pond at Wodonga Racecourse and Recreation Reserve.

Figure 4-56 Looking upstream at erosion in one of the tributaries of Jack-in-the-Box Creek, upstream (south) of Victoria Cross Parade.

4.7.1.2 Vegetation Condition

The natural vegetation within this reach is mapped as being EVC175 Grassy Woodland upstream of Victoria Cross Parade and EVC55 Plains Grassy Woodland (Victorian Riverina Bioregion) downstream. The scale of this mapping would not have been fine enough to classify a riparian EVC and it is likely the riparian strip would have been a Creekline Grassy Woodland.

The vegetation condition in this upper catchment is variable but does contain areas of relatively high-quality woodland with few woody weeds. The undeveloped woodlands (Figure 4-56), synonymous with EVC175, have a young to medium aged canopy of Gum and Box species. Native shrubs are scarce, but the ground layer contains a relatively high percentage cover of native grasses. Woody weeds are well controlled to absent in most of the woodland (Jack Perry Reserve) upstream of Victoria Cross Parade.

The open swale leading from the Army Barracks to Victoria Cross Parade is acting as a retarding basin and is vegetated with a variety of native rushes (e.g. Cumbungi) and sedges. The creek lines on the downstream/northern side of Victoria Cross Parade pass through some remnant woodland and modified/straightened channels. These open channels pass beside the racecourse and through industrial areas where access to the creek is limited. Interpretation of aerial photography suggests that there is a near continuous cover of native trees along the channels through to the railway line, where after the creek is piped.

4.7.1.3 Trajectory and Management Implications

- **Further development is planned within the Jack in the Box Creek catchment. Water Sensitive Urban design techniques and appropriate riparian vegetation management is required to minimise changes to downstream hydrology, hydraulics and sediment transport rates.**
- **Sediment management practices from the White Box Rise development area are poor to non-existent and requires attention to minimise sediment input into downstream reaches and sediment pond maintenance requirements.**
- **Dispersive soils are present within this reach. Dispersive soils are vulnerable to tunnel, sheet and gully erosion processes.**
- **Without intervention, the erosion located upstream of Victoria Cross Parade is expected to worsen. The presence of dispersive soils in this area will complicate the required mitigation works arrangement.**
- **The stormwater treatment at the Wodonga Racecourse is likely to be effective at removing the large sediment particles sourced within this reach, however the finer sediment will likely remain suspended and therefore flow into downstream reaches, impacting upon water quality.**
- **The relatively intact woodland within Jack Perry Reserve is likely to have an improving condition trajectory if invasive weeds can be controlled. The new subdivision to the west is likely to have an effect on the reserve (e.g. garden escapes, rubbish and green waste dumping, firewood collection, domestic pet impacts on native fauna). Acknowledgement and management of these impacts is likely to be required and ongoing to prevent degradation of vegetation, fauna and habitats within the reserve.**
- **The creek lines downstream of Victoria Cross Parade will require ongoing weed management to ensure native vegetation is not suppressed and the channel is not choked.**
- **The riparian vegetation corridor within Jack Perry Reserve provides an important ecological link to Bears Hill.**

4.7.2 The Piped Reach

The Piped Reach of Jack-in-the-Box Creek is a 1.5-kilometre section that extends from the old railway line (150m upstream of Thomas Mitchell Drive) to Osburn Street (Figure 4-51). The land adjoining the Piped Reach is predominately urban and light industry. The grassed swale above the pipe is managed as informal parkland with scattered Eucalyptus trees, mowed grass, concrete walking tracks and play equipment.

4.7.2.1 Physical Condition

Jack-in-the-Box Creek exists as an underground pipe overlain by an open grassed swale throughout this reach (Figure 4-57). The grassed swale conveys flows greater than the pipe capacity. The underground pipe arrangement is very efficient at conveying water, sediments and any pollutants that are collected from the contributing catchment. The pipe presents a physical barrier for amphibious and aquatic fauna to migrate in Jack-in-the-Box.

The underground pipe discharges into an open junction pit at Osburn Street. The Junction pit also receives stormwater from the east and west. At the time of the inspection the discharge from the Jack-in-the-Box Creek pipe was milky white in appearance (Figure 4-58).

Figure 4-57 Jack-in-the-Box Creek grass swale in Arthur Dunstan Park.

Figure 4-58 Junction pit at Osburn Street. Note the milky water to the left of the junction pit.

4.7.2.2 Vegetation Assessment

This reach is characterised by the presence of individual and lines of indigenous and non-indigenous native trees over mown exotic grass in combination with a sparse shrub cover. Observed species in this reach include Red Gum (indigenous) White Cedar, Silky Oak and Lemon Scented Gum (non-indigenous natives) and the occasional exotic ornamental tree.

4.7.2.3 Trajectory and Management Implications

- **The underground pipe arrangement is very efficient at conveying water, sediments and any pollutants that are collected from the contributing catchment into downstream reaches.**
- **The pipe presents a physical barrier for amphibious and aquatic fauna.**
- **In its current form, there is limited opportunity to improve the ecological function and value of this reach.**
- **Vegetation management of the swale overlaying the drain should consider the primary function of the swale (i.e. to convey flows above the drain capacity). It is likely that the primary flow path within the swale will be kept clear of woody vegetation.**
- **There is a clear decline in water quality within the creek through presence of discoloured water at the open junction pit on Osburn Street. This decline in water quality is likely associated with untreated urban/industrial run-off.**

4.7.3 Lower Reach

The Lower Reach of Jack-in-the-Box Creek extends from Osburn Street to the confluence with Wodonga Creek. This reach flows through an industrial precinct before flowing under the old railway line and Hume Freeway (Figure 4-51). Additional surrounding land uses include commercial and public reserve land.

4.7.3.1 Physical Condition

It is understood that the channel characteristically fills with sediment within this reach. In response to the deposition, Council periodically excavates sediment. Deposition will typically occur in this reach, likely due to:

- A reduction in flow energy, associated with a reduced channel/hydraulic slope within this reach.
- The efficient transportation of sediment sourced from upstream reaches through the piped reach.

The Hume Freeway and Bandiana Link Road cross over the Jack-in-the-Box Creek approximately 200 metres upstream of the confluence with Wodonga Creek. Jack-in-the-Box Creek runs through culverts for 180 metres under the roadways. The culverts will provide a barrier to fish passage and act as a hydraulic control in large flow events.

4.7.3.2 Vegetation Condition

The woody riparian vegetation from Osburn past Kendall Street to the old railway line is almost exclusively exotic (Figure 4-59). There are patches of Red Gum canopy trees close to the old rail line and on the downstream side of the freeway to Wodonga Creek (Figure 4-60), however these patches are infested with Willow, Blackberry and Privet.

A rare Wallaby Grass apparently exists within this reach (Vivid Consulting, 2015), however could not be confirmed through the site assessment.

Figure 4-59 Woody weed infested riparian zone adjacent to Kendall Street.

Figure 4-60 A Red Gum patch near the old railway line adjacent Jack in the Box Creek.

4.7.3.3 Trajectory and Management Implications

- **Deposition is likely to continue to occur in this reach, likely due to:**
  - **A reduction in flow energy, associated with a reduced channel/hydraulic slope within this reach.**
  - **The efficient transportation of sediment sourced from upstream reaches through the piped reach.**
- **Sediment extraction has the potential to contribute to channel instabilities and increase sediment transport rates within this reach. Further investigation is required to determine the impacts associated with the periodic sediment extraction activities.**
- **The rare Wallaby Grass apparently present within this reach (Vivid Consulting, 2015), was not located during the site assessment. The presence and abundance of the Wallaby Grass should be confirmed. Suitable protection measures should subsequently be undertaken.**
- **The vast majority of the riparian zone from Osburn Street to the railway line is heavily infested with woody weeds and is in very poor condition. This section will remain in poor condition under the current management regime and requires extensive weed control and revegetation to improve conditions.**
- **The Red Gum dominated Floodplain Riparian Woodland vegetation, that is present from upstream of the railway line to the Wodonga Creek confluence, is in a stable to declining condition as there are woody weeds (e.g. Willow and Blackberry) amongst the trees that are limiting natural regeneration. The condition could be improved with regular weed control and enhancement revegetation (e.g. planting of understorey species).**

4.8 Middle Creek

Middle Creek forms at the northern foot of the hills that separate Leneva and the Indigo Valley. Middle Creek flows north west through agricultural land, largely following the Beechworth-Wodonga Road through to Boyes Road, where Beechworth-Wodonga Road deviates to the north. Middle Creek continues in a north westerly direction, past the eastern end of Bears Hills, along the rear of the old Bandiana sale yards and the military complex, before discharging into the Kiewa River. The assessment of this reach was restricted to isolated site visits and aerial photography interpretation due to both time and access constraints.

For the purpose of this project, Middle Creek has been separated into three reaches (Figure 4-61), namely:

- Upper Reach.
- Mid Reach.
- Lower Reach.

A condition summary map is provided in Appendix A.

Figure 4-61 Middle Creek reaches.

4.8.1 Upper Reach

The Upper Reach of Middle Creek extends from the headwaters to where Beechworth-Wodonga Road intersects Middle Creek (Figure 4-61).

4.8.1.1 Physical Condition

The Upper Reach of Middle Creek transitions from a confined valley setting into a partly confined valley setting and is surrounded by moderately steep hill slopes that have been substantially cleared for grazing. The channel has undergone substantial bed deepening within this reach (Figure 4-62). Consequently, several floodplain

surface levels exist along this reach (Figure 4-62). Additionally, bed deepening within the primary channel has likely triggered deepening within the tributary network (Figure 4-63). It is probable that bedrock impingements limit the upstream propagation of bed deepening in the upper section of the creek and tributary network.

A review of available aerial photography indicates that numerous bank instabilities are present within this reach, primarily but not exclusively situated on outside bends. Discrete bedrock impingements are also evident, which provide a lateral and possible vertical control of the channel at these discrete locations. In-stream geomorphic units include pools, riffles, runs and bars. The observed channel instabilities are likely exacerbated by unrestricted stock access and an absence of riparian vegetation.

Figure 4-62 Incised channel of Middle Creek showing unrestricted stock access to the channel.

Figure 4-63 Silver Creek, a tributary of Middle Creek, has deepened, likely in response to deepening within Middle Creek.

4.8.1.2 Vegetation Assessment

The riparian vegetation within this reach was likely to have been characteristic of a Creekline Grassy Woodland (EVC 68) prior to European settlement. Despite substantial clearing and channel change (erosion), some of this vegetation character and structure remains. What remains in this upper reach is typically a discontinuous narrow line of native and exotic trees, primarily in the form of willows. There are a number of areas that have been fenced and revegetated, however the majority appears to be subject to unrestricted grazing pressure.

4.8.1.3 Trajectory and Management Implications

- **The extent, nature and trajectory of the erosion processes within the Upper Reach of Middle Creek could not be determined within the scope of this project. Further investigation is therefore required. It is possible that some sections within this reach are in the process of re-attaining bed and bank stability, negating the need for widespread hard engineering bank stabilisation works.**
- **On-going channel erosion within this reach is partially attributed to and exacerbated by the increased in-channel flows (associated with channel enlargement), unrestricted stock access and an absence of suitable riparian vegetation.**
- **On-going erosion within this reach likely contributes sediment into downstream reaches.**
- **Native vegetation is likely to be on a trajectory of improvement in fenced and revegetated areas and on a declining trajectory where grazing is unrestricted. The spread of woody weeds such as willows also threatens native vegetation and habitats within the reach.**

4.8.2 Mid Reach

The Mid Reach of Middle Creek extends from the Beechworth-Wodonga Road to approximately one kilometre upstream of Kiewa Valley Highway (Figure 4-61).

4.8.2.1 Physical Condition

The Mid Reach of Middle Creek is located with a laterally unconfined valley setting, that is, the channel is generally free to migrate across the valley floor. Whilst the dominant adjacent land use is broad scale grazing, a considerable portion of the reach has been fenced to exclude stock pressure. This appears to have contributed to improve in-channel vegetation cover and bank stability within this reach. Despite the improved bank stability compared to the upstream reach, isolated bank erosion is present throughout the reach. This bank erosion is commonly but not exclusively situated on outside bends (Figure 4-64).

A series of rock chutes (bed grade control structures) are present downstream of Frederic Street Road (Figure 4-65). These rock chutes provide an important function in maintaining channel stability within this reach.

The contributing catchment of this area is contained within the Leneva growth corridor. Wodonga Council have developed a Waterway Masterplan for the N1 tributary (an unnamed tributary of Middle Creek) which is contained within one of these development areas.

Figure 4-64 Bank erosion occurring on the outside bend and deposition occurring on the inside of the bend.

Figure 4-65 A rock chute situated in Middle Creek downstream of Frederic Street Road. The rock chute is providing an important function in maintaining channel stability.

4.8.2.2 Vegetation Condition

The vegetation condition and structure along the Mid Reach of Middle Creek is highly variable. Key observations associated with this reach, observed primarily through aerial photo interpretation include:

- A considerable portion of the reach has been fenced from stock pressures and been subject to weed removal and revegetation activities. Where stock have been excluded, in-channel vegetation appears to be present.
- There are several long discontinuities or complete absent sections of riparian vegetation.
- Uniquely, some established vegetation stands are set back from the creek channel.
- A discontinuous coverage of woody weeds, most likely willows are present along the reach.

4.8.2.3 Trajectory and Management Implications

- **The vegetation condition and trajectory are highly variable within this reach. Areas lacking remnant native woody vegetation, or areas subjected to unrestricted grazing (generally downstream from Frederic Street Road) are likely to decline in condition.**
- **Stock exclusion through fencing appears to have had considerable positive influence on in-stream vegetation presence and channel stability. Stock exclusion and revegetation works are strongly encouraged in this reach.**
- **Further development is planned within the surrounding catchment as part of the Leneva Growth Corridor. Water Sensitive Urban design techniques and appropriate riparian vegetation management is required to minimise changes to downstream hydrology, hydraulics, channel stability and sediment transport rates.**

- **Wodonga Council have developed a Waterway Masterplan for the N1 tributary (an unnamed tributary of Middle Creek) which is contained within one of the proposed development areas. Waterway management recommendations for this tributary in context of the proposed development and the existing waterway condition are provided in the Waterway Masterplan.**
- **A series of rock chutes (bed grade control structures) are present downstream of Frederic Street Road. These rock chutes provide an important function in maintaining channel stability within this reach, particularly as further development is planned within this reach. The structures should be regularly monitored and maintained as necessary.**
- **With much of the reach being fenced off to manage stock access and revegetation works occurring within the reach, the resilience and stability of the channel is expected to improve.**

4.8.3 Lower Reach

The Lower Reach of Middle Creek extends from approximately one kilometre upstream of the Kiewa Valley Highway to the confluence with the Kiewa River (Figure 4-61).

4.8.3.1 Physical Condition

The Lower Reach of Middle Creek transitions out of its own valley and onto the broader Kiewa River floodplain within this reach. The longitudinal channel slope reduces in this reach, contributing to a reduction in flow energy. As such, bank stabilities appear to be less frequent as the creek progresses towards the Kiewa River.

There are a number of floodplain channels that regularly engage during overbank flow events. The culverts under Whytes Road likely provide a hydraulic constraint during moderate flow events, with Whytes Road periodically inundated.

Willows colonise the channel downstream of Whytes Road and through to the Kiewa River. The willows are likely influencing bed form and have the potential to contribute to channel instabilities if further colonisation and encroachment occurs.

4.8.3.2 Vegetation Condition

The vegetation within this reach would once have been a Floodplain Riparian Woodland (EVC56), which characteristically are dominated by Red Gums. In its current form, this reach is highly modified with willows now dominating the riparian zone (Figure 4-66, Figure 4-67). Common Reed is also abundant within and surrounding the creek channel where grazing is absent (Figure 4-66).

Figure 4-66 Willows and Common Reed dominate the floodplain upstream of the Kiewa Valley Highway.

Figure 4-67 Willows occupy the channel downstream of Whytes Road.

4.8.3.3 Trajectory and Management Implications

- **Further development is planned within the surrounding catchment as part of the Leneva Growth Corridor. Water Sensitive Urban design techniques and appropriate riparian vegetation management is required to minimise changes to downstream hydrology, hydraulics, channel stability and sediment transport rates.**
- **Bank stabilities appear to be less frequent as the creek progresses towards the Kiewa River, likely associated with a reduction in flow energy.**
- **The willows are likely influencing bed form and have the potential to contribute to channel instabilities if further colonisation and encroachment occurs.**
- **The riparian zone within this reach lacks native woody vegetation and is dominated by willows. The condition will remain poor under current management practice and will only improve if willows are controlled and native revegetation occurs.**

4.9 Yackandandah Creek

Yackandandah Creek is the largest Tributary of the Kiewa River and has a catchment of approximately 400 Square kilometres (ID&A 2000). The headwaters of Yackandandah Creek are located at an elevation of over 1100 metres with the catchment extending to the alluvial plains of the Kiewa Valley at an elevation of approximately 200 metres (Water Technology 2010). Yackandandah Creek has been significantly altered by historic gold mining operations that took place from 1850s to 1930. **A thorough Waterway Action Plan (Water Technology, 2009) was prepared by the North East CMA, extending from Yackandandah through the Kiewa River.** The Waterway Action Plan encompassed the portion of Yackandandah Creek within the project area, which encompasses a 6km reach from Lindsay Road, Staghorn Flat through to the confluence with the Kiewa River (Figure 4-68). The relevant reaches are referred to as:

- The Staghorn Flat Reach.
- The Kiewa Reach.

The following summary associated with Yackandandah Creek has been drawn from the Yackandandah Creek Waterway Action Plan (Water Technology 2009). A condition summary map is provided in Appendix A.

Figure 4-68 Yackandandah Creek reaches.

4.9.1 Staghorn Flat Reach

The Staghorn Flat Reach of Yackandandah Creek extends approximately 3.5 kilometres from Lindsay Road downstream to the Kiewa Valley Highway (Figure 4-68).

4.9.1.1 Physical Condition

Yackandandah Creek has an irregular and low sinuosity planform with the Staghorn Flat Reach. The channel is partly confined between the valley margin and terraces. Sherrard (1990 as cited in Water Technology 2010) states that the channel course has been relocated during the hydraulic dredging in serval section of this reach including upstream of the Murray Valley Highway.

The Staghorn Flat Reach appears to have been subject to straightening as a direct consequence of dramatic increase in bed load caused by historic mining activities (Sherrard, 1990 as cited in Water Technology 2010). In some locations the channel has over widened as a result of historic mining. Where this has occurred, a low flow meandering channel has formed, and inset floodplain features have developed.

Since the cessation of mining in the catchment, the Staghorn Flat Reach has been subject to bed deepening processes. This is evident at the confluence with minor tributaries.

Within the Staghorn Flats Reach, bank erosion typically occurs on outside bends with corresponding deposition occurring on the opposite bank, indicating that he erosion is associated with meander bend development. The main factors resisting the erosion in this reach are vegetation, albeit largely exotic species (willows and poplars), and the fine, cohesive bank material. A number of pile field sites have been constructed within this reach to manage the erosion (Figure 4-69). These pile fields have generally passed their design life and are contributing little to bank stability.

Despite fencing along the creek, stock access was prevalent throughout the majority of the reach.

Figure 4-69 Black Willow planted at the toe of the bank behind pile fields. Pile field works have frequently been implemented in conjunction with exotic vegetation plantings.

4.9.1.2 Vegetation Condition

The woody vegetation along the Staghorn Flats Reach is largely continuous and dominated by exotic species. The riparian vegetation corridor rarely exceeds the width of two trees or 15m with the surrounding floodplain mostly cleared of native vegetation.

The exotic vegetation within this reach is dominated by Willow and Poplar species (Figure 4-70) with Black Willows, Crack Willows the dominant species. In a number of locations willows are growing within the channel, both as individuals and in groups. The in-stream willows were largely juvenile Crack Willows and Black Willows and mature Black Willows. In some instances, the instream willows infestations are forming significant in-stream blockages. Juvenile Poplars are also present in-stream, however much less frequent.

Other exotic weed species present in this reach include Hawthorn, False Acacia, Fig, Fleabane, Prunus, Lucerne, Mint, Phalaris, Nightshade, Maple, Spear Thistle, Creeping Buttercup, Desert Ash, Purple Top, English Broom, Briar Rose, Gorse and Paterson's Curse.

With exotic species largely dominating in-stream (Figure 4-71) and on the bank face, native vegetation is largely limited to the top of the bank or beyond. Native regeneration is generally low within the reach. Unrestricted stock access is damaging existing stands of Phragmites.

The large amount of exotic deciduous vegetation has the potential to contribute to water quality issues during autumn months with extensive leaf fall smothering macroinvertebrates and reducing dissolved oxygen levels during decomposition.

Figure 4-70 Looking downstream at the right bank. This section of stream has been subject to exotic vegetation plantings to manage erosion. Crack Willow has been planted on the inset floodplain (in the foreground), Black Willow on the bank toe and poplars on the top of the bank.

Figure 4-71 Looking downstream at Black Willow growing in the channel bed. In-stream willows are frequent within this reach.

4.9.1.3 Trajectory and Management Implications

- **In response to a reduction in sediment supply in this reach, the bed of the creek has deepened. This trend is likely to continue into the future.**
- **The existing willows and other woody weeds are contributing to the bed form and channel stability in many areas within this reach. Any willow management works undertaken within this reach will need to consider the role the willows provide in relation to channel stability. Conversely, as the willows age, they will have an increasing tendency to collapse into the channel, potentially contributing to bank instabilities.**
- **Willows and poplars also often occur where they do not contribute to bed or bank stability. These exotic species should be managed without the requirement of further investigation.**
- **Native vegetation and habitat condition are compromised by the abundance of woody weeds in this reach. Woody weed control and revegetation mostly with understorey species, would generate condition improvements and is considered a priority for management.**

4.9.2 The Kiewa Reach

The Kiewa Reach extends approximately 2.7 kilometres, from the Kiewa Valley Highway through to the confluence of the Kiewa River (Figure 4-68).

4.9.2.1 Physical Condition

Yackandandah Creek enters the floodplain of Kiewa River downstream of the Kiewa Valley Highway. The creek has an irregular, low sinuosity planform through this reach. The channel is laterally unconfined and has a relatively flat bed gradient.

Within the Kiewa Reach, Yackandandah Creek appears to have avulsed multiple times, resulting in a wholesale shift in the channel. The avulsive nature is evident through a number of paleo features across the valley floor.

Historically, the Kiewa Reach appears to have both aggraded and degraded. Aggradation has occurred as a result of the liberation of large volumes of sediment from the upstream reaches. This sediment has deposited with the Yackandandah Creek and on the surrounding floodplain. The large volumes of sediment depositing in Yackandandah Creek may have contributed to the avulsive nature of the creek as it developed shorter, steeper and more hydraulically efficient flow paths. Sediment has also been conveyed through the reach to the Kiewa River where it is now a sand slug downstream of Yackandandah Creek (Figure 4-72).

The geomorphic diversity is generally poor within this reach as a result of the large volumes of sediment depositing and being transported through this reach and the lack of large woody debris.

Steep raw banks were frequently present on outside bends throughout this reach, with large sand point bars present on inside bends. It is expected that these outside banks will erode during high flow events.

Stock have unrestricted access to the Yackandandah Creek throughout this reach and are impacting on the bank stability with access tracks present in numerous locations (Figure 4-73).

Figure 4-72 Looking downstream within the Kiewa River, immediately downstream of the Yackandandah Creek – Kiewa River confluence.

Figure 4-73 Stock have unrestricted access throughout the Kiewa Reach of Yackandandah Creek. Access tracks on the bank face are common through this reach.

4.9.2.2 Vegetation Condition

The riparian vegetation corridor through the Kiewa Reach is generally considered poor with the vegetation being discontinuous and a mix of native and exotic species. The exotic vegetation is dominated by Willow

species including Pussy Willow, Crack Willow, Weeping Willow and Black Willows (Figure 4-74). The willows are present both in-stream and along the banks. Other exotic weed species present include Blackberry, Hawthorn, English Broom, Poplar, Bathurst Burr, Common Thorn Apple, Spear Thistle and Fleabane.

Native vegetation is dominated by River Red Gums with a mixture of age classes present. Native shrubs were uncommon throughout the reach and were limited the individual occurrences of Tea Tree, Ovens Wattle and Silver Wattle. Phragmites were also present throughout the reach however the health and potential cover was likely impacted by stock.

Figure 4-74 Typical section the Kiewa Reach, showing straight channel, scattered native and exotic vegetation.

4.9.2.3 Trajectory and Management Implications

- **The Waterway Action Plan found that that reach will be subject to net deposition over time. Revegetation and large woody debris placement within the Kiewa Reach would reduce the transport and export of sediment to the Kiewa River.**
- **Continued aggradation of the lower section of the Kiewa Reach will increase the frequency of flood flows. Existing LiDAR should be used to identify any potential avulsion channels and any flood runners leading to flow re-entry points into Yackandandah Creek and the Kiewa River both upstream and downstream of the confluence. Such sites should be a focus of revegetation works to forestall potential erosion and development of alternate stream courses.**
- **Without management intervention, the presence of highly invasive weed species will likely result in an increase in exotic vegetation coverage throughout this reach. Species of particular concern include pussy willow, Black Willow, Crack Willow, Blackberry, English Broom, Spear Thistle and Paterson's Curse.**
- **Unrestricted stock access is compromising the physical condition of the reach through the formation of tracks and limiting the regeneration of native woody species and Common Reed.**

4.10 Kiewa River

The Kiewa River has its headwaters in the Alpine National Park extending to an elevation of over 1900 metres. The Kiewa River heads North through the cleared Kiewa Valley, until its confluence with the Murray River, to east of Wodonga. Within the project area, the Kiewa River is a low land meandering river, located to the east of Wodonga. The subject reach of Kiewa River is limited to the reach contained within the Wodonga City Council region. This reach stretches from Barton Lane, Staghorn Flat, to the confluence with the Murray River (Figure 4-75) and is inclusive of Finns Creek, a tributary stream and developing anabranch of the Kiewa River. Finns Creek is not fully connected to the Kiewa River at the upstream end, however it presents as an avulsion risk. A condition summary map is provided in Appendix A.

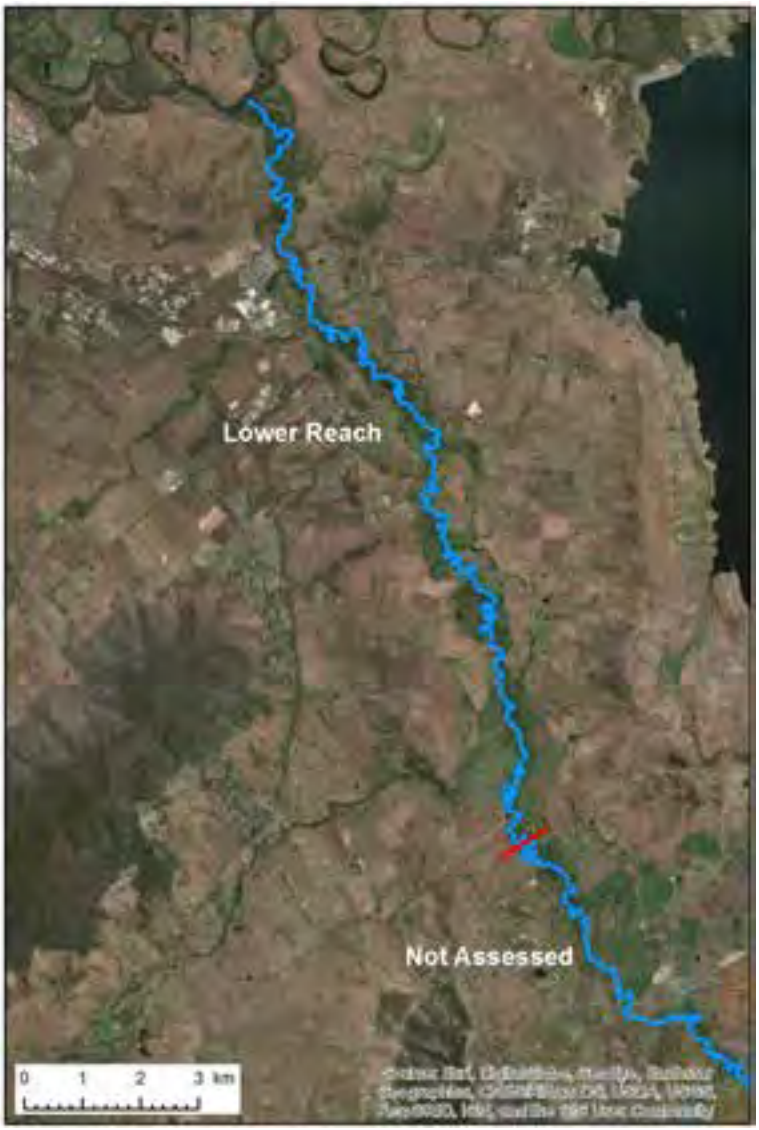

Figure 4-75 Kiewa River reaches.

4.10.1.1 Physical Condition

Within the project extent the Kiewa River is unconfined, meandering lowlands river. The unconfined nature of the river means that it can migrate across the floodplain, via meander migration (eroding outside bends and deposition occurring on the inside of bends) and through avulsions (wholesale changes in the rivers planform).

Paleo features, including ox bow lakes and flood channels, are located across the floodplain. The numerous Ox bow lakes that are present along the floodplain of the Kiewa River have formed through meander bends being cut off. Finns Creek is a developing flood channel of the Kiewa River and poses an avulsion threat.

Meander migration is the dominant geomorphic process occurring in the Kiewa River within the project extent (Figure 4-76). Bank erosion rates will be exacerbated on outside bends where riparian vegetation is absent. Many outside bends along the project reach of the Kiewa River are colonised by willows, which are contributing to channel stability. This reach of the Kiewa River provides important aquatic habitat for native fish species and provides a connection to the Murray River system downstream. Sediment inputs from Yackandandah Creek are negatively impacting upon the aquatic habitat values downstream.

The development of Finns Creek has been managed through the placement of several rock armoured grade control structures.

Figure 4-76 Outside bend located downstream of the Murray Valley Highway. Note the absence of riparian vegetation. Bank erosion has occurred across this outside bend.

4.10.1.2 Vegetation Condition

The banks of the Kiewa River within this reach are discontinuously lined with Willows, mature Red Gums and occasional native understorey shrubs. The downstream half of the reach generally has improved Red Gum canopy cover along the banks and across the adjacent floodplain. Willows in particular are compromising the habitat and native vegetation values of the river and causing a hazard to recreational users.

4.10.1.3 Trajectory and Management Implications

- **A thorough condition investigation of the Kiewa River could not be undertaken within the scope of this Waterway Action Plan. A Waterway Action Plan was developed for Finns Creek and the Lower Kiewa River (Earth Tech, 2004). This report is out of date and requires revisiting to determine appropriate management strategies across the reach.**

- **Meander migration is the dominant in-channel geomorphic process occurring in the Kiewa River within the project extent.**
- **The existing willows are contributing to channel stability in many areas within this reach. Any willow management works undertaken within this reach will need to consider the role the willows provide in relation to channel stability. Conversely, as the willows age, they will have an increasing tendency to collapse into the channel, potentially contributing to bank instabilities.**
- **Finns Creek presents as an avulsion risk to the Kiewa River. On-going monitoring and maintenance will be required to manage this enduring risk.**
- **Woody weeds, particularly Willows, compromise the native vegetation and habitat conditions of the river. Removal of woody weeds and the planting of native species will improve the condition of the river.**

4.11 Wodonga Creek

Wodonga Creek is an anabranch of the Murray River and is managed as part of the River Murray system by the NSW Soil Conservation Service. A comprehensive management plan for Wodonga Creek already exists. As such, Wodonga Creek has not been included in this Plan. Information and management recommendations for Wodonga Creek can be found in the River Management Plan – Wodonga Reach Management Zone (Earth Tech 2005).